INSTRUCTION MANUAL

REGATRON

POWER SUPPLY

MODEL 229A

SERIAL No 0578

ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED

EATONTOWN · NEW JERSEY

TELEPHONE: (201) LIberty 2-0300 TWX: (201) 542-2273 CABLE: ELMEASCO

Warranty

Electronic Measurements instruments are guaranteed to be free from defects in material and workmanship for one year from the date of purchase (except for tubes, fuses and batteries). Our liability under this warranty is limited to repairs and adjustments or replacements of defective parts or instruments when the fault is a direct result of defective materials or workmanship in the manufacture of the apparatus. This warranty covers service for the first year, except for transportation to and from the factory. If any fault develops in the equipment, the following steps should be taken:

1. Notify ELECTRONIC MEASUREMENTS CO., INC. Give full particulars of the difficulty and include the serial number of the instrument in question. On receipt of this information, we will give you service information or shipping instructions.

2. On receipt of shipping instructions, forward the appartus to us, prepaid, and we will make repairs and adjustments immediately at the factory.

3. If the fault has been caused by misuse, or abnormal conditions of operation, as disclosed by our examination, repairs will be billed at cost. In this case, an estimate of the cost will be submitted before work is started.

ELECTRICAL STANDARDS

All company primary standards are either certified directly or are traceable to certification by the National Bureau of Standards.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument received comprehensive visual and electrical inspections before shipment. Immediately upon receipt from the carrier, and before operation, this instrument should be inspected visually for damage caused in shipment. If such inspection reveals internal or external damage in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. When referring to this instrument, always include the model and serial numbers.

REGATRON®
PROGRAMMABLE
POWER SUPPLY

MODEL 22 9AL-B

SERIAL No. _____

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

COPYRIGHT 1962

ELECTRONIC MEASUREMENTS COMPANY, INC.

Eatontown, New Jersey

Printed in U. S. A.

TABLE OF CONTENTS

Page

SECTION 1, DESCRIPTION

1-1. INTRODUCTION 1
1-2. PROGRAMMING 1
1-3. OVERVOLTAGE 1
1-4. CONSTANT-CURRENT OUTPUT 1
1-5. CHOPPER STABILIZATION 1

SECTION 2, OPERATION

Figure 2-1. Front Panel 2
2-1. INSTALLATION 2
2-2. CONTROLS AND TERMINATIONS 2
2-3. FUSES 2
2-4. PRELIMINARY 2
2-5. LINE AND LOAD CONNECTIONS 2
2-6. LOCAL OPERATION 3
Figure 2-2. Remote Sensing Connections, Local Operation 3
2-7. REMOTE SENSING, LOCAL 3
2-8. USE OF REAR TERMINATIONS 3
2-9. PROGRAMMED OPERATION 3
Figure 2-3. Programmed Operation 3
2-10. REMOTE SENSING, PROGRAMMED 4
2-11. PROGRAMMING CONSIDERATIONS 4
2-12. PROGRAMMING SUGGESTIONS 4
Figure 2-4. Programming With Stepper Switch 4
2-13. OVERVOLTAGE OPERATION 4
Figure 2-5. Overvoltage Operation 5
2-14. REFERENCE AGING 5
2-15. EXTERNAL REFERENCE CONNECTION 5
2-16. USE AS VOLTAGE STANDARD 5
Figure 2-6. Conversion to Constant-Current Operation 5
2-17. CONVERSION TO CONSTANT-CURRENT 5
2-18. CHOPPER STABILIZED OPERATION 6

SECTION 3, CIRCUITRY

3-1. GENERAL 7
3-2. CONTROL SYSTEM, LOCAL AND PROGRAMMED 7
Figure 3-1. Output Control Configuration 7
3-3. REGULATOR SYSTEM, GENERAL 7
3-4. UNREGULATED DC SUPPLY 7
3-5. REFERENCE 7
3-6. SERIES AMPLIFIERS 8
3-7. BALANCED INPUT DETECTOR 8
3-8. DRIVER AMPLIFIER 8
3-9. CHOPPER STABILIZATION 8
3-10. OUTPUT CIRCUITRY 8

SECTION 4, MAINTENANCE

4-1. PARTS REPLACEMENT 9
4-2. NULL ADJUSTMENT 9
4-3. NULL ADJUSTMENT FOR CHOPPER STABILIZED VERSION . . . 9
4-4. CALIBRATION 9
Figure 4-1. Calibration Methods 9
4-7. SERIES TUBE FAULTS 10
4-8. CLEANING AND LUBRICATION 10
4-9. TROUBLE SHOOTING TABLE 10
4-10. TABLE OF RESISTANCES 12
4-11. TABLE OF VOLTAGES 12
Figures 4-2 and 4-3. Parts Location 13
PARTS LIST 14

REGATRON MODEL 229A

TABLE OF SPECIFICATIONS

OUTPUT
0 to 150 volts, 0 to 300 ma.

REGULATION
Line: 0.1% or 0.1 volts, whichever is greater, for line change from 105 to 125 volts ac, 50-60 cps.
Load: 0.1% or 0.1 volts, whichever is greater, no load to full load.

REGULATION WITH CHOPPER STABILIZATION
Line or load: 0.01% or 0.003 volt, whichever is greater.

STABILITY: Within 0.1% or 50 millivolts, whichever is greater, for 8 hours after 30 minutes warm up, under fixed line, load, and temperature conditions with precision high stability external programming resistor.

STABILITY WITH CHOPPER STABILIZATION: 0.05% + 2 millivolts, same conditions as above.

RIPPLE: 1 millivolt RMS maximum, with positive or negative output grounded.

OUTPUT IMPEDANCE: Less than 0.01 ohm at low audio frequencies; 0.1 ohm to 10 KC; 1 ohm to 40 KC.

TRANSIENT RESPONSE: For step change from no load to full, or full to no load, output recovers to within dc regulation limits of initial value within 1 millisecond.

OVERVOLTAGE CAPABILITY: See paragraph 2-13.

REMOTE PROGRAMMING RESISTANCE: 1000 ohms-per-volt of output.

REMOTE SENSING: See paragraphs 2-7 and 2-10.

AMBIENT TEMPERATURE RANGE: -20°C to +45°C.

OUTPUT POLARITY: Swinging link for positive or negative ground or floating output.

CIRCUIT PROTECTION: Input ac line fused, dc output fused.

TERMINATIONS: Front: 5-way insulated binding posts. Rear: barrier-type terminal strips. Line cord is 3-conductor type.

CONTROLS: DC CONTROL and 50-volt VERNIER are of wirewound type. Panel calibration is approximate.

MOUNTING: Unit fits 19" standard racks and is equipped with rubber feet for table mounting. Top and bottom are protected by perforated metal covers.

FINISH: Smooth gray semi-gloss enamel Class 2 per MIL-E-15090.

INPUT POWER REQUIRED: 193 watts at full load, input 125 volts ac, 60 cps.

DIMENSIONS: 5-1/4 inches high, 12-3/4 inches deep, 19 inches wide.

WEIGHT: 26 pounds, approx.

SECTION 1

DESCRIPTION

1-1. INTRODUCTION. This Regatron Programmable Power Supply is a wide-range source of voltage-regulated dc power, continuously adjustable in output from zero to 150 volts. It is designed for laboratory or systems applications requiring well regulated, stable dc potentials capable of resolution to values in the fractional volt region. It affords the user facilities for remote control of voltage output (see next paragraph) as well as local, front panel control. Further detailed performance data is presented in the Specifications Table on the opposite page.

1-2. PROGRAMMING. The output voltage of this power supply can be controlled remotely, or programmed, with a low power resistor connected to the REM and + output terminals. Output voltage then depends directly on the value of the programming resistor in the ratio of 1 volt per 1000 ohms. This relationship remains constant over the entire output voltage range, even at a fraction of a volt. In programmed operation, regulation and stability are maintained within specified ratings. See paragraph 2-9 for instructions on programmed operation.

1-3. OVERVOLTAGE. Voltage output greater than the specified maximum is available at reduced output current. See paragraph 2-13 for instructions on overvoltage operation.

1-4. CONSTANT-CURRENT OUTPUT. This unit can be converted from constant-voltage to constant-current output by means of a simple external connection. See paragraph 2-17.

1-5. CHOPPER STABILIZATION. Chopper stabilization contributes improvements in regulation and stability which are described in the Table of Specifications and explained in paragraph 3-9. For units originally supplied without chopper stabilization, a conversion kit is available to incorporate this feature, or the unit may be returned to the factory for conversion.

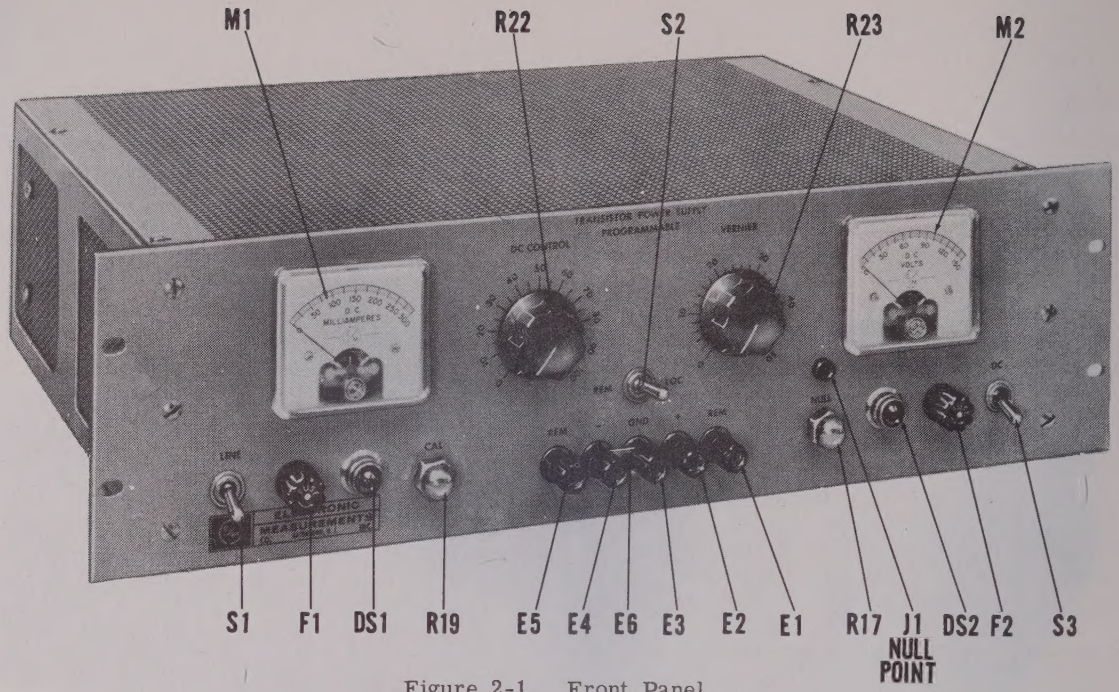

Figure 2-1. Front Panel

SECTION 2

OPERATION

2-1. INSTALLATION. This unit operates on 105 to 125 volts, 50 to 60 cycles, single-phase ac. Input power required is stated in the Specifications Table.

The equipment may be table or rack-mounted in a standard 19-inch rack. The rubber mounting feet may be removed from the bottom cover if they interfere with other rack-mounted equipment. Sufficient clearance should be allowed above and below the unit to provide adequate ventilation. The top dust-cover may be removed, if desired, to increase the ventilation.

2-2. CONTROLS AND TERMINATIONS. (See Figure 2-1.)

a. LINE switch: controls ac line input.

b. DC switch: controls regulated dc output.

c. REM-LOC switch: permits local or remote programmed control.

d. DC CONTROL: for adjustment of output voltage through 100 volts, calibrated to dial markings on panel.

e. VERNIER: for continuous fine adjustment through 50 volts. VERNIER and DC CONTROL settings are additive.

f. TERMINALS: +, GND, and — for connection of load. A swinging link permits connection of either the positive or negative side of high voltage to chassis ground.

g. REM terminals: with + and — terminals, for connection of programming resistor and for remote sensing connections.

h. TB1 (on rear of chassis): for connection of external voltage reference. See paragraph 2-15.

i. NULL adjustment: for zeroing of balanced input detector. See paragraph 4-2.

j. CAL adjustment: for adjustment of output to panel markings or for exact 1000 ohms-per-volt programmed operation. See paragraph 4-4.

2-3. FUSES. This unit contains the following fuses mounted on the front panel:

F1 - 5 amps (at left), in ac line input circuit.

F2 - 3/8 amp (at right), in + dc output circuit, to protect against short circuit or overloads.

2-4. PRELIMINARY. Before connecting to ac power, check that:

a. LINE switch is off.

b. DC switch is off.

c. DC CONTROL and VERNIER are at minimum, fully counterclockwise.

d. REM-LOC switch is at appropriate position: at LOC for panel control, at REM for remotely programmed operation.

e. Swinging link is at desired grounding position, or removed for floating output.

2-5. LINE AND LOAD CONNECTIONS.

a. Connect line cord to ac power outlet.

b. Connect load to + and — output posts. It should be noted that the regulation of this unit is measured at the output posts. To maintain the specified regulation in actual service, the load wires must be heavy enough to prevent substantial voltage drops between the output posts and the load.

2-6. LOCAL OPERATION.

a. Throw LINE switch on: green indicator should light.

b. Set DC CONTROL to the desired voltage as indicated on the panel or voltmeter. This can be a coarse setting, and if greater resolution is desired the VERNIER, which is additive, can provide the fine setting.

c. Turn VERNIER to precise voltage desired. For an output of 50 volts or less, set DC CONTROL to zero and select output with VERNIER alone to realize greater stability.

d. After one minute, throw DC switch on: red indicator should light. Desired voltage is now applied to load.

NOTE

Always allow a one minute warm up period from a cold start before throwing DC switch on. This switch, when off, shorts the + and — output posts, thus effectively preventing application of any excess voltages to load during warm up. Subsequently, the DC switch can be thrown on or off with no danger of exceeding the desired output voltage.

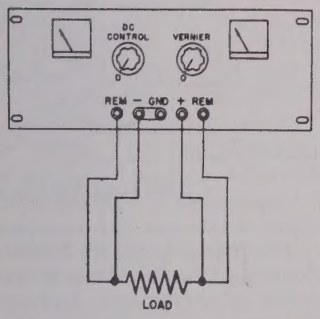

Figure 2-2. Remote Sensing Connections, Local Operation

2-7. REMOTE SENSING, LOCAL. For remote sensing in local operation, throw the REM-LOC switch to REM, connect a lead from the + REM post out to the + termination on the load, and from the — REM post out to the — termination on the load, and proceed as in paragraph 2-6.

2-8. USE OF REAR TERMINATIONS. On units equipped with rear-mounted terminations only, the preceding operating instructions apply without change. On units equipped with both front and rear terminations, the following additional procedure applies to local operation from the rear terminals:

a. Throw REM-LOC switch to REM.

b. On rear terminal board, connect REM posts to adjacent output posts. In remotely programmed use, either set of terminations can be employed in the normal manner as described in paragraphs 2-9 and 2-10. Control will then be derived from the set of terminals in use.

2-9. PROGRAMMED OPERATION. As stated in paragraph 1-2, the output of this power supply can be controlled from a remote point, or programmed, with a resistor. For programmed operation, proceed as follows:

a. Throw DC and LINE switches off.

b. Throw REM-LOC switch to REM.

c. Connect the load and programming resistor as shown in figure 2-3A. Output voltage depends on programming resistance in the ratio 1: 1000. For example, to obtain 50 volts, use a 50,000 ohm resistor.

d. Throw LINE switch on.

e. Set DC CONTROL and VERNIER to zero.

f. Throw DC switch on. Programmed voltage is now applied to load.

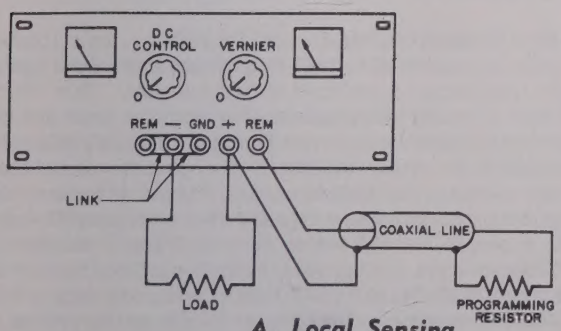

Figure 2-3. Programmed Operation

2-10. REMOTE SENSING, PROGRAMMED. Where load and control resistor are far from the unit, but near each other, the method illustrated in figure 2-3B will eliminate the effect of voltage drops in the output leads, yielding remote sensing for regulation at the load.

2-11. PROGRAMMING CONSIDERATIONS. The following considerations should be carefully noted before programming this power supply:

a. An open in a remote control circuit is effectively a high programming resistance and, accordingly, will cause an uncontrolled voltage rise to maximum output. To avoid damage to the load or repeated blowing of the dc fuse, provision should be made to prevent opens. For the same reason, it is necessary that make-before-break switches be used in any multiple-voltage programming arrangement, as in figure 2-4.

b. Unless the programming resistor itself is physically shunted across the REM and + terminal posts, it is desirable to use shielded or coaxial cable, as shown in figure 2-3A, to prevent injection of ripple and noise from external sources. An insulated cable, such as RG58/U is recommended because the coaxial sheath carries output potential.

c. For long term or permanent programmed operation, it is advisable to short out the internal controls. This will eliminate possible disturbance of programmed voltage by accidental rotation or vibration of the DC CONTROL or VERNIER, and generally will yield greater stability.

d. Programmed operation can be combined with use of the internal controls when convenient or necessary, merely by omitting step e. of paragraph 2-9, and adjusting controls to any desired value. In this case, the value of the programming resistor will be added to the values to which the internal controls are adjusted, and the total resistance will determine output voltage.

2-12. PROGRAMMING SUGGESTIONS. Although the above programming instructions are illustrated with a single fixed resistor as the remote control, it is evident that variable resistors, driven potentiometers, or fixed resistors wired to stepping switches can be employed to deliver voltages in a wide variety of time/amplitude patterns.

The time required for switching from one programmed voltage to another varies from the seconds range to the milliseconds range, depending upon conditions. Modifications for special switching times are available on special order from the factory.

It is also evident that programming can be manually or automatically actuated. As an example of automatic programming, figure 2-4 illustrates a four level rotary switch, each level of which controls one Regatron supply. As illustrated, the entire battery can be stepped through a sequence of seven programmed outputs upon command.

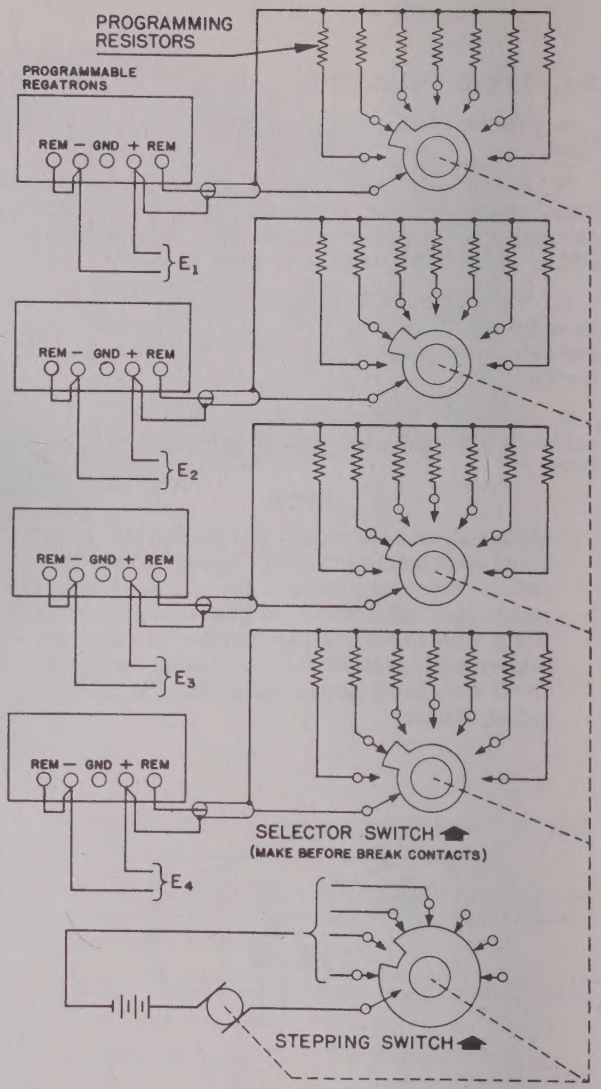

Figure 2-4. Programming With Stepper Switch. Each Level Controls One Regatron Power Supply.

In an extensive system, a central board may contain the switches or rheostats for the programming of several Regatron power supplies in different locations. In such a system, it is practical to calibrate the control elements directly to dial markings. Note that the accuracy of calibration depends upon the accuracy of the resistances and/or the dial markings.

2-13. OVERVOLTAGE OPERATION. This power supply is capable of voltage output higher than the specified maximum at reduced output current. For overvoltage an external programming resistor must be employed to substitute for or add to the DC CONTROL and VERNIER in order to extend the control resistance range and thus the output range. Figure 2-5 gives the applicable current deratings for overvoltage operation. For example, at 175 volts, this model will deliver up to 220 ma. This voltage output can be obtained by setting the DC CONTROL and VERNIER to zero, and connecting a 175,000 ohm programming resistor as described in paragraphs 2-9 and 2-10 and shown in figure 2-3A and 2-3B. Alternatively, the controls can be set for 100 volts, with an external 75,000 ohm programming resistor.

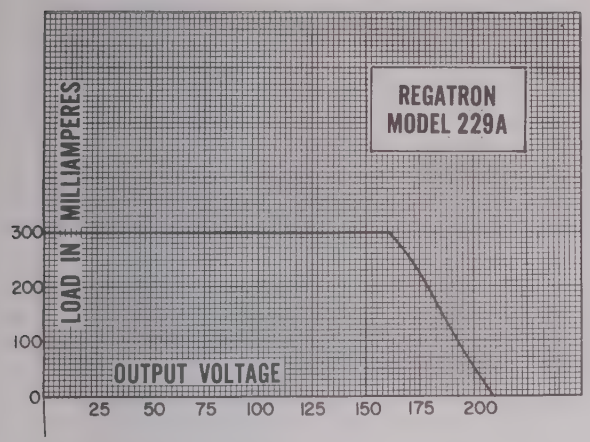

Figure 2-5. Overvoltage Operation, Showing Current Deratings

2-14. REFERENCE AGING. The voltage reference tube employed in this power supply exhibits progressive change of voltage with aging, typically, 0.5% for 1000 hours of use. The resulting error at the output remains at a constant percentage throughout the voltage range of the power supply, but the absolute error varies directly with the output setting. Periodic calibration by the method described in paragraph 4-4 may be performed to eliminate any error due to aging of the reference tube.

2-15. EXTERNAL REFERENCE CONNECTION. If higher accuracy is required than is provided by the internal reference, a stable external reference source of at least 85 volts can be employed. The external reference source is connected via the rear-mounted terminal board TB1 as follows:

a. Remove the link across terminals 1 and 2 of TB1.

b. Connect the external reference across terminals 2 and 3 with the positive at terminal 3.

An external reference between 85 and 87 volts may be directly connected as described. Above 87 volts, each additional volt requires the insertion of 1000 ohms of resistance between the external reference and terminal 3 on TB1 of the power supply. Thus an external reference of — 150 volts requires a resistor of 63,000 ohms ±1%. The resistor should be a wirewound type using high stability alloy, since it directly affects the stability of the output voltage from the power supply.

2-16. USE AS VOLTAGE STANDARD. If a precision decade box is available for use as a remote programming control, this power supply will serve as a voltage standard, the accuracy of which, (neglecting aging of the reference)will be only slightly poorer than that of the decade box, even for a decade accuracy of 0.1%.

With the decade box connected as the remote programming resistor, output voltage will be indicated directly by the decade dials. Thus, the thousand ohm per step dial indicates volts, the 10,000 per step dial indicates tens of volts, and the 100,000 per step dial indicates hundreds of volts.

In voltage-standard use, the power supply should be calibrated as described in paragraphs 4-5 and 4-6. Error due to aging of the internal reference can be nullified by periodic recalibration. If an external reference is to be employed, the calibration should be performed after connection of the external source (paragraph 2-15). It is also evident that for minimal drift, the chopper-stabilized version of this power supply should be employed.

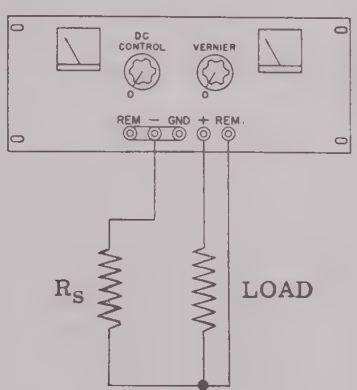

Figure 2-6. Conversion to Constant-Current Operation

2-17. CONVERSION TO CONSTANT-CURRENT. For conversion from constant-voltage to constant-current output, proceed as follows:

a. Select a sample resistor, R_S in figure 2-6 above, which will carry the load current and develop a sample voltage for the control system. To determine its value, select a sample voltage. Five to 10 volts is a good range. Although the voltage may be made as high as desired, it must be remembered that the sample voltage

subtracts from the available output voltage. If E_S is the sample voltage and I_L is the desired load current, then $R_S = E_S/I_L$, where R_S is in ohms and I_L is in amperes. The actual wattage will be $E_S \times I_L$. The resistor used should have a suitably higher wattage rating.

b. Make connections as shown in figure 2-6 and set both panel controls to zero.

c. Throw REM-LOC switch to REM.

d. Throw the LINE switch on.

e. Bring current up to the desired value by turning the VERNIER up to the voltage selected as the sample in step a. above. In constant-current operation, the VERNIER is the output control for sample voltages up to 10 volts. The conversion described above provides good dc regulation. The ac impedance of the power supply, however, is relatively low, and this should be noted in considering applications.

2-18. CHOPPER-STABILIZED OPERATION. As stated in the Specifications Table, this unit achieves regulation of 0.01% or 3 mv, and stability of 0.05% +2 mv for 8 hours when equipped with chopper stabilization. Although both ratings are conservative, note that the stability figure is specified with the unit in programmed operation using an external resistor of high electrical (and in the case of a variable resistor) high mechanical stability. This rating can be realized only in such operation, and with the internal controls shorted out or set to zero to prevent them from contributing variations resulting from accidental rotation or vibration.

SECTION 3

CIRCUITRY

NOTE

Circuit references are made to the schematic diagram, except where indicated.

3-1. GENERAL. This power supply employs a full wave rectifier, the positive output of which is applied to series amplifiers controlled by the regulator loop. The resulting regulated dc voltage constitutes the output.

3-2. CONTROL SYSTEM, LOCAL AND PROGRAMMED. Figure 3-1 illustrates the output control configuration in simplified form. If inputs G_1 and G_2 are equal ($E_D = 0$) then:

$$\frac{E_O}{E_R} = \frac{R_1}{R_2} \text{ and } E_O = E_R \times \frac{R_1}{R_2}$$

where E_O = regulated output voltage
E_R = internal reference voltage
and R_2 is a fixed resistor.

Since E_R and R_2 are constant, $E_O = KR_1$; or, the output voltage is dependent only upon the value of R_1 which, in local operation of the power supply, consists of the DC CONTROL and VERNIER. In programmed operation, R_1 is the remote programming resistor. In either local or programmed operation, the voltage output = $0.001R_1$, or, 1000 ohms control resistance per volt of output.

In practice, R_2 can be adjusted with the CAL control (on the panel) for exact 1000 ohms-per-volt programmed operation, or to calibrate output with panel dial markings.

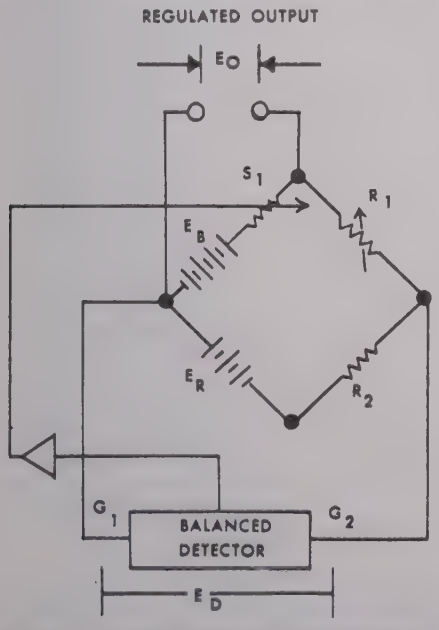

Figure 3-1. Output Control Configuration

3-3. REGULATOR SYSTEM, GENERAL. The regulator system employs a balanced input detector, V9, connected from the zero point of the input bleeder to the negative reference point (minus) to detect departures from balance. The amplifier error is applied to a high gain amplifier, V6, which drives the grids of the series amplifiers V10 through V12 in such a manner as to overcome the error. Because of the high gain of the system the error at equilibrium is very small. A gas tube, V5, maintains a very stable reference potential, and v/r tubes V1, V2, V3, and V4 maintain steady potentials for the tubes of the regulator system.

3-4. UNREGULATED DC SUPPLY. The main dc supply employs four Type CER71 silicon diodes in a full wave rectifier bridge, with filtering provided by a 320 UF electrolytic capacitor, C1. An 82K bleeder resistor, R2, which draws approximately 2 ma, discharges C1 upon turn-off of the power supply. Four rectifiers in a full wave bridge comprise the 270 volt screen supply for series amplifiers V10 through V12, with filtering by an 80 UF electrolytic capacitor C2. This screen supply, the negative of which is returned directly to the cathodes of the series amplifiers, also serves as plate supply for the 6AU6 driver amplifier, V6. Selenium rectifiers CR9, CR10, and CR11 deliver positive supply voltage to v/r tube V1, with capacitor C3, 40 UF, as filter. Rectifiers CR12, CR13, and CR14 deliver negative supply voltage to v/r tube V3, with capacitor C4 as filter.

3-5. REFERENCE. The internal reference potential for the power supply, also employed as a regulated service potential for the cathode of V6, is obtained across a gas-filled 85A2 tube, V5, which maintains a very stable drop of approximately -85 volts. CAL control R19 permits calibration of the control system to a precise output voltage based upon the exact potential across V5, and permits periodic recalibration to eliminate error resulting from aging of V5. When an external reference is employed (see paragraph 2-15) tube V5 is removed from the control system by the removal of the link across terminals 1 and 2 on TB1, but continues to supply -85 volts to V6.

The -150 volts from v/r tube V1, a type OA2, is dropped by R5 to 108 volts and further regulated by an OB2 tube V2 for use on the plates of the balanced input detector V9, and for the tube in the chopper-stabilizer unit on models so equipped.

The -150 volts from V3 is similarly dropped to -108 volts by R8, further regulated by V4, and utilized for the cathodes of V9 and the negative end of the voltage divider network composed of V7, V8 and R14 and R15. A 1 megohm resistor, R6, applies a momentary, high firing potential to v/r tube V4; this drops to 108 volts

when the tube begins to conduct. A type 1N34A diode, CR15 functions as a one-way switch. CR15 disconnects V4 from the junction of R8 and R9 to permit momentary application of the high firing potential through R6. As soon as V4 has fired, CR15 closes the path from the junction of R8 and R9, permitting normal flow through V4 and removing the momentary firing potential.

3-6. SERIES AMPLIFIERS. Paralleled Type 6550 beam power pentodes V10 through V12 are employed as series elements, or variable conductances. Control grids are direct-coupled to the plate of the driver amplifier V6. The cathodes of V10 through V12, from which positive, regulated output voltage is obtained, are removed from the + output terminal when DC switch S3 is thrown off. Throwing S3 off also shorts the + output terminal to minus to protect the power supply and the load from surges during standby operation.

3-7. BALANCED INPUT DETECTOR. A 12AX7 cathode-coupled amplifier V9 is employed as a balanced input detector, grid 7 of which is effectively at the positive of the reference potential, and grid 2 at the other null point on the opposite side of the control bridge. Regulated plate supply is taken from V2, and cathodes are returned through R16 to -108 volts regulated by V4. The NULL control R17 permits setting of the balanced input detector to zero difference between grids; capacitor C7 bypasses degenerative ac components appearing across R17.

Output from plate 6 of V9 is applied across a coupling and voltage divider network consisting of EM10 glow discharge regulator tubes V7 and V8 and resistors R15 and R14. The glow tubes couple plate potential to the grid of V6, maintaining a constant voltage drop which permits the grid to follow the potential at the plate of V9, thus constituting an effective dc coupling which avoids any substantial loss of gain.

Note that the chopper-stabilized version of this power supply employs a 12AY7 in place of the 12AX7 for tube V9.

Standard models include a ballast regulator tube, RT1, which maintains a stable 6.3 volts ac across the heater of V9. However, the ballast tube is not required in the chopper-stabilized version, and the RT1 socket is therefore employed for the chopper-stabilizer plug-in unit, with the slight wiring changes shown on the schematic diagram.

3-8. DRIVER AMPLIFIER. This stage employs a 6AU6 pentode, V6, in high gain, low current "starved" operation. Output is direct-coupled to the control grids of the series amplifiers, completing the regulator system loop.

3-9. CHOPPER-STABILIZATION. On units so equipped, the chopper-stabilizer is installed across the grids of the balanced input detector. Without chopper-stabilization this stage is subject to drift, with the result that output voltage may change up to .1% or 50 millivolts for 8 hours. The stabilizer unit, utilizing a contact modulator (chopper) continually samples the offset at grid 2 of V9, rectifies and filters it, and applies the resulting correction signal via reference grid 7 (removed from minus in chopper-stabilized version) to the regulator system to reduce the net offset to a vanishingly small value. The chopper-stabilizer adds a gain of approximately 1000 to the regulator, with the result that regulation, as well as stability, improves to the figure shown in the Specifications Table.

3-10. OUTPUT CIRCUITRY. Connected across the output terminals are a resistor, R24 and a large electrolytic capacitor, C9, the values of which are selected to adjust the characteristic of the feedback loop for stable operation. Also across the output is a diode, CR16 which protects the external load by presenting a low impedance to any reverse voltage which may develop when the unit is shut off. A type NE2 neon glow lamp, DS3, serves as a clamp to protect the internal reference, V5, from voltage surges when the power supply is switched from a high to a low voltage in remote control (programmed) operation. DS3 fires momentarily but is otherwise normally inoperative.

It should be noted that throwing the REM-LOC switch to REM removes the positive side of the reference from the minus side of the high voltage. This connection must be re-established via the programming connections shown in figure 2-3.

SECTION 4

MAINTENANCE

Attention is called to the Warranty under which this equipment is sold, to be found at the front of this book.

4-1. PARTS REPLACEMENT. An electrical parts list accompanies the schematic diagram in Section 5 of this book, and along with the parts location illustrations, will identify all parts to be replaced. In general, replacement parts are completely defined by the values and tolerances indicated on the parts list. The following components, however, require special attention.

a. V1, V2, V3 and V4—Replacement of any of these tubes will affect null balance, which should therefore be readjusted as per paragraph 4-2.

b. V5—Replacement of the 85A2 will change the internal reference voltage somewhat, and necessitate recalibration as per paragraph 4-4. If the replacement 85A2 does not yield approximately correct calibration, or proves unstable, a satisfactory tube will be furnished by the factory upon request.

c. DC CONTROL and VERNIER controls—If either of these wirewound potentiometers is defective, it is advisable to obtain an exact replacement. If none is available locally, an order should be addressed to the factory. Any temporary substitute potentiometer should provide an arc of 280° effective rotation for the panel dial markings to represent output correctly.

4-2. NULL ADJUSTMENT. The NULL control, located on the front panel, permits adjustment of the balanced input detector to null, or zero level. This adjustment, which holds over the entire operating range, is made as follows:

a. Remove the acorn nut covering the control.

b. With the DC CONTROL and VERNIER at zero, throw the LINE switch on. After a minute (from cold start) throw the DC switch on.

c. Connect a voltmeter across the output + and — posts. Use 3 volt dc scale or lower.

d. Adjust the NULL control for zero on the meter. A very sensitive indication can be obtained by alternately connecting and disconnecting the meter lead.

4-3. NULL ADJUSTMENT FOR CHOPPER-STABILIZED VERSION. The NULL control on the chopper-stabilized version should be set to maximum resistance for optimum operation. No attempt should be made to adjust the NULL control to zero, as described above, with the chopper-stabilizer unit removed.

4-4. CALIBRATION. The CAL control, also found on the front panel, requires adjustment for any one of three reasons:

For close agreement between panel markings and output, or for exact 1000 ohms-per-volt ratio in programmed output, or for recalibration to either of the above after replacement of V5.

This adjustment can be performed in either of two ways: with an accurate voltmeter or with an external, precise source of voltage.

4-5. If an accurate voltmeter is employed, proceed as follows, referring to figure 4-1A.

a. Remove acorn nut covering CAL control. Connect meter across + and — terminals.

b. To calibrate panel markings, turn VERNIER to zero and set DC CONTROL to 150. Throw LINE, then DC switches on and adjust CAL control for 150 volt reading on the external voltmeter.

c. To calibrate for exact 1000 ohms-per-volt programmed output, turn VERNIER and DC CONTROL to zero. Set up for programmed operation with a 150K resistor, and adjust CAL control for 150 volts on the external voltmeter.

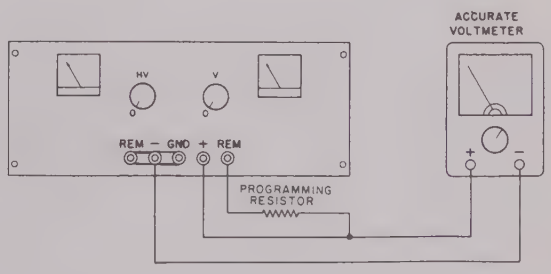

Figure 4-1A. Calibration—With Accurate Voltmeter for Exact 1000-ohm-per-volt Programming

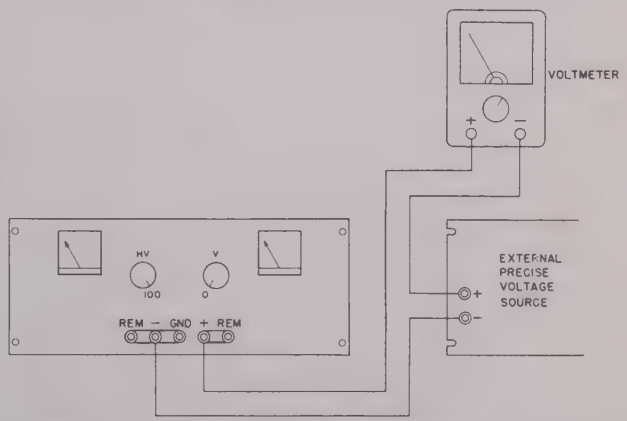

Figure 4-1B. Calibration With External, Precise Voltage Source

4-6. If an external, precise source of voltage is employed, proceed as follows, referring to figure 4-1B.

a. Connect the negative outputs of the unit and the external voltage source together.

b. Connect an accurate voltmeter between the positive terminals of the Regatron unit and the external source.

c. Set the external source to exactly 150 volts.

d. To calibrate panel markings, perform step c and turn VERNIER to zero. Throw LINE then DC switches on, and adjust CAL control for a zero reading on the external voltmeter. Use the lowest dc meter range available.

e. To calibrate for exact 1000 ohms-per-volt programmed output, perform step c and turn VERNIER and DC CONTROL to zero. Program with a 150K resistor. Throw LINE, then DC switches on, and adjust CAL control for zero on the external meter.

4-7. SERIES TUBE FAULTS. In selecting replacement series tubes, or when a malfunction appears to result from a faulty series tube, the following procedure is recommended:

a. Remove all series tubes but one.

b. Turn on unit, apply 1/N of full load current at a low voltage, where N = number of series tubes.

c. Check ripple and regulation.

d. Remove this series tube, place another series tube in another socket, and repeat steps b and c. Repeat steps b and c for every other socket and tube, taking one at a time.

e. If one or more series circuits tests faulty, repeat the test in each case with a tube known to be satisfactory. If the repeated test proves favorable it may be assumed that the previous tube is defective. Otherwise the associated circuit should be checked for faults.

4-8. CLEANING AND LUBRICATION. This power supply employs forced air cooling and, after extended service, considerable dust will be deposited on most surfaces within the unit. About twice a year the cover should be removed and all parts, and particularly the fan blades, should be cleansed free of dust and grime. Lubricate the fan motor once or twice a year by squeezing a few drops of light machine oil into the lubrication holes of the bearing straps.

4-9. TROUBLE-SHOOTING TABLE. Referenced below are several possible symptoms of troubles which can develop, with their most likely causes, and remedies. This table is intended to serve as a brief guide in trouble shooting.

SYMPTOM	CAUSE	REMEDY
1. Unit is dead when LINE switch is thrown on.	a. Fuse F1 blown. b. Fuse F1 open, defective.	a. Replace with 5 amp fuse. b. Check F1 for continuity and replace if necessary.
2. Fuse F1 blows repeatedly.	a. Rectifier (CR1, 2, 3, or 4) shorted. b. Rectifier (CR9 through CR14) shorted. c. Rectifier (CR5 through CR8) shorted.	a. Replace. b. Replace. c. Replace.
3. DC fuse F2 blows, output to zero.	a. Short circuit load. b. Overload, above 300 ma. c. Fuse F2 open, defective. d. With load connected, DC CONTROL or VERNIER potentiometer is open. e. With load connected, external control line open. f. Diode CR16 shorted (across output terminals).	a. Check load. b. Check load. c. Check F2 for continuity and replace if necessary. d. Check R22, R23 for resistance. See paragraph 4-1. e. Check external control line. f. Replace.

	SYMPTOM		CAUSE		REMEDY
4.	No control of output, voltmeter pins at top of scale.	a.	6550 series amplifier V10 through V12 shorted.	a.	Replace. See paragraph 4-7. Also check screen and cathode resistors of affected series stage.
		b.	6AU6 amplifier V6 inoperative.	b.	Replace.
		c.	DC CONTROL or VERNIER potentiometer open.	c.	Check R22, R23 for resistance. See paragraph 4-1.
		d.	In remote (REM) programmed operation, external control resistor open.	d.	Check external control resistor.
5.	No control of output, voltmeter at zero, fuse F2 not blown.	a.	6550 series amplifier V10 through V12 defective.	a.	Replace. See paragraph 4-7.
		b.	12AX7 balanced input detector V9 defective.	b.	Replace.
		c.	Ballast tube RT1 defective.	c.	Replace.
6.	Voltmeter indication disagrees with control settings at full scale.	a.	Unit out of calibration.	a.	Recalibrate.
7.	Output voltage lower than control setting but recalibration impossible or out of CAL range.	a.	85A2 reference tube V5 shifted voltage.	a.	Replace. See paragraph 4-1. Also recalibrate.
		b.	OA2, V3, defective.	b.	Replace.
8.	Output voltage lower than control setting in chopper-stabilized unit.	a.	Tube V1 (12AX7) in chopper-stabilizer unit defective.	a.	Replace.
9.	Poor line regulation.	a.	Defective V1, V2, V3, V4, V5, or V9.	a.	Replace. See paragraph 4-1.
		b.	Defective rectifier (CR1, 2, 3, or 4).	b.	Replace.
10.	Poor load regulation.	a.	Poor load connections or high resistance in load leads.	a.	Check load connections.
		b.	6550 series amplifier V10 through V12 defective.	b.	Replace. See paragraph 4-7.
		c.	Chopper inoperative.	c.	Replace chopper.
11.	Excessive zero-offset (drift) in chopper-stabilized unit.	a.	Tube V9 defective.	a.	Replace.
		b.	Chopper inoperative.	b.	Replace chopper.
12.	NULL adjustment impossible.	a.	Fuse F2 blown.	a.	Replace.
		b.	Defective V1, V2, V3, V4, V5, V7, V8 or V9.	b.	Replace.
13.	High ripple.	a.	External control resistor and control line are coupling stray ac signal to unit.	a.	Shield control and/or line.
		b.	Defective V3, V4, V5, V6, or V9.	b.	Replace.
		c.	Defective C1, C2, C3, C8, or C9.	c.	Replace.
14.	DC changes abruptly at a periodic rate.	a.	Defective V1, V2, V3, V4, V5, or V7 or V8.	a.	Replace. Recalibrate if V5 is replaced.

4-10. TABLE OF RESISTANCES. The following table applies to both standard and chopper-stabilized versions. Values in the table are nominal and may vary as much as 20% among production units without causing difficulties. Conditions of measurement:

a. Ac line cord not connected to power.

b. No load connected.

c. LINE and DC switches off. Chassis ground floating, (swinging link disconnected from + or — post). LOC-REM switch at LOC.

d. DC CONTROL at 0. VERNIER at 0.

e. Readings from indicated tube pins to minus output post.

RESISTANCES

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	4.7 MEG	NC	NC	NC	NC	NC	0	—	—
V2	4.7 MEG	NC	NC	NC	NC	NC	0	—	—
V3	0	NC	NC	85K	NC	NC	NC	—	—
V4	0	NC	NC	95K	NC	NC	NC	—	—
V5	0	NC	NC	75K	NC	∞	NC	—	—
V6	510K	75K	0	0	5 MEG	200K	75K	—	—
V9	4.7 MEG	0	220K	0	0	5 MEG	0	220K	2Ω
V10 thru V12	NC	∞	82K	4.7 MEG	∞	NC	∞	135K	—

4-11. TABLE OF VOLTAGES. The values in the Table of Voltages below are nominal and may vary as much as 20% among production units without causing difficulties. The measurements were made with a 100,000 ohms-per-volt meter, under the following conditions:

a. LINE input 115 volts ac. LINE and DC switches on.

b. DC CONTROL at 90, VERNIER at 10.

c. No load connected.

d. Chassis ground floating, (swinging link disconnected from + or — post). LOC-REM switch at LOC.

e. Readings from indicated tube pins to minus post.

VOLTAGES

All voltages are dc unless noted.

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	150	NC	NC	NC	NC	NC	0	—	—
V2	108	NC	NC	NC	NC	NC	0	—	—
V3	0	NC	NC	-150	NC	NC	NC	—	—
V4	0	NC	NC	-108	NC	NC	NC	—	—
V5	0	NC	NC	-85	NC	0	NC	—	—
V6	-87	-85	6.3 VAC	0	60	-41	-85	—	—
V9	108	0	.8	6.3 VAC	6.3 VAC	33	0	.1	0
V10 thru V12	NC	0	230	370	60	NC	0	100	—

ELECTRONIC MEASUREMENTS CO., INC. ADDENDUM #2061

PARTS LIST CHANGE

MODEL 229A-AK

8-21-62 Change as follows:

CR15,- diode, silicon	HC-69	Solitron

PARTS LIST 11/61

MODELS 229A/AK PROGRAMMING CONSTANT: 1000npv

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
B1	Motor, shaded pole, 115V, 50-60 CPS, 4 in. fan blade	DYAB-570-3	Barber-Colman
*C1	Capacitor, electrolytic, 320 UF, 300 VDC, insl. sleeve	D31962	Sprague
*C2	Capacitor, electrolytic, 80 UF, 300 VDC, insl. sleeve	D31964	Sprague
*C3,9	Capacitor, electrolytic, 40 UF, 450 VDC, insl. sleeve	D19939	Sprague
*C4	Capacitor, electrolytic, 80 UF, 450 VDC, insl. sleeve	D15911	Sprague
C5	Capacitor, mica, 15 UUFD ±5%, 500 VDC	CM20B150J	Micamold
C6	Capacitor, mica, 220 UUFD ±5%, 500 VDC	CM20B221J	Micamold
*C7	Capacitor, electrolytic, 25 UF, 25 VDC, insl. sleeve	KE-25/25	Frako
C8	Capacitor, mylar, 0.5 UF +20% -10%, 400 VDC	Type 2110-BM	Chicago Cond.
*CR1-CR8,CR16	Rectifier, silicon	CER71	Solitron
*CR9-CR14	Rectifier, selenium	8J1	Radio Receptor
*CR15	Diode, germanium	1N34A	Sylvania
Cord	Line cord, 7' lg. #18 gauge, 3 cond., 3 prong plug	346-B-52	EMC
*DS1,2	Lamp, 6.3V., 0.25A.	44	G.E.
*DS3	Lamp, neon	NE-2	EMC
E1,2	Posts, binding, red	29-3R	Grayhill
E3,4,5	Posts, binding, black	29-3B	Grayhill
E6	Shorting link	938-L	General Radio
E7	Shorting link	141-J	Cinch-Jones
*F1	Fuse, cartridge, 5A.	3AG5	Sightmaster
*F2	Fuse, cartridge, 3/8A.	3AG3/8	Sightmaster
J1	Tip jack, nylon (black)	105-603	E.F. Johnson
J3	Socket, octal, (stabilizer unit or RT-1)	9977	Cinch-Jones
M1	Milliammeter, 0-300 MADC ±2% full scale	Model 649/MA300	EMC
M2	Voltmeter, 0-150 VDC ±2% full scale	Model 649/V150	EMC
R1	Resistor, fixed, WW, vitreous enamel, 3 ±5%, 25W	25F3	Ward Leonard
R2	Resistor, fixed, comp, 82 ±10%, 2W	HB-8231	Allen-Bradley
R3	Resistor, fixed, comp, 4.7 megohms ±10%, ½W	EB-4751	Allen-Bradley
R4	Resistor, fixed, WW, vitreous enamel, 10K ±5%, 20W	Type 'Brown Devil'	Ohmite
R5	Resistor, fixed, comp, 5100 ±5%, 1W	GB-5125	Allen-Bradley
R6	Resistor, fixed, comp, 1 megohm ±10%, ½W	EB-1051	Allen-Bradley
R7	Resistor, fixed, WW, vitreous enamel, 5000 ±5%, 10W	10X5000	Ward Leonard
R8	Resistor, fixed, comp, 3600 ±5%, 1W	GB-3625	Allen-Bradley
R9	Resistor, fixed, comp, 5600 ±5%, 1W	GB-5625	Allen-Bradley
R10	Resistor, fixed, WW, vitreous enamel, 50000 ±5%, 10W	10X50000	Ward Leonard
R11,14	Resistor, fixed, comp, 330K ±10%, ½W	EB-3341	Allen-Bradley
R12	Resistor, fixed, comp, 390K ±10%, ½W	EB-3941	Allen-Bradley
R13,15	Resistor, fixed, comp, 100K ±10%, ½W	EB-1041	Allen-Bradley
R16	Resistor, fixed, comp, 150K ±10%, 1W	GB-1541	Allen-Bradley
*R17	Resistor, variable, WW, 3000 ±5%, 2W, linear taper, ¼ in. dia. by ⅛ in. lg. slotted shaft, series 43	CM18923	Clarostat
R18	Resistor, fixed, comp, 220K ±10%, 1W	GB-2241	Allen-Bradley
*R19	Resistor, variable, WW, 10K ±5%, 2W, linear taper, ¼ in. dia. by ⅛ in. lg. slotted shaft, series 43	CM18924	Clarostat
*R20	Resistor, fixed, WW, 76K ±1%, 3W	Type P3-W	Precision Resistor
*R21	Resistor, fixed, WW, 3000 ±1%, ½W	Type TX-178	Precision Resistor
*R22	Resistor, variable, WW, 100K ±5%, 4W, linear taper, ¼ in. dia. by ½ in. lg. shaft, series 10	CM18927	Clarostat
*R23	Resistor, variable, WW, 50K ±5%, 3W, linear taper, ¼ in. dia. by ⅜ in. lg. shaft, series 58	CM20403	Clarostat
R24	Resistor, fixed, WW, 1 ±5%, 1W	Type BW1	Int'l Resistance
R25,28,31	Resistor, fixed, comp, 82 ±10%, 1W	GB-8201	Allen-Bradley
R26,29,32	Resistor, fixed, comp, 470 ±10%, 1W	GB-4711	Allen-Bradley
R27,30,33	Resistor, fixed, comp, 10 ±10%, 1W	GB-1001	Allen-Bradley
*RT1	Ballast tube	AMP 3-4	Amperite
*S1	Switch, toggle, SPST	160-73	Carling Electric
*S2	Switch, toggle, DPST	2BK62-73	Carling Electric
*S3	Switch, toggle, DPDT	2GL53-73	Carling Electric
T1	Transformer, power & filament	5038	EMC
TB1	Barrier strip, 3 terminal	3-141-Y	Cinch-Jones
TB2	Barrier strip, 5 terminal (rear termination only)	5-141-Y	Cinch-Jones
*V1,3	Electron tube	0A2	RCA
*V2,4	Electron tube	0B2	RCA
*V5	Electron tube	85A2/0G3	Amperex
*V6	Electron tube	6AU6	RCA
*V7,8	Electron tube	EM10	EMC
*V9	Electron tube (229A)	12AX7	RCA
*V9	Electron tube (229AK)	12AY7	G.E.
*V10,11,12	Electron tube	6550 or KT-88	Tung-Sol British Ind.
XDS1	Holder assembly, pilot lamp, green faceted lens	100	Drake Mfg.
XDS2	Holder assembly, pilot lamp, red faceted lens	100	Drake Mfg.
XF1,2	Extractor post, fuse, miniature	342003	Littelfuse
XV1-XV6	Socket, 7 pin, miniature	53P24022	Cinch-Jones
XV9	Socket, 9 pin, noval	14502	Cinch-Jones
XV10,11,12	Socket, 8 pin, octal	9751-9	Eby

* Recommended spare parts.

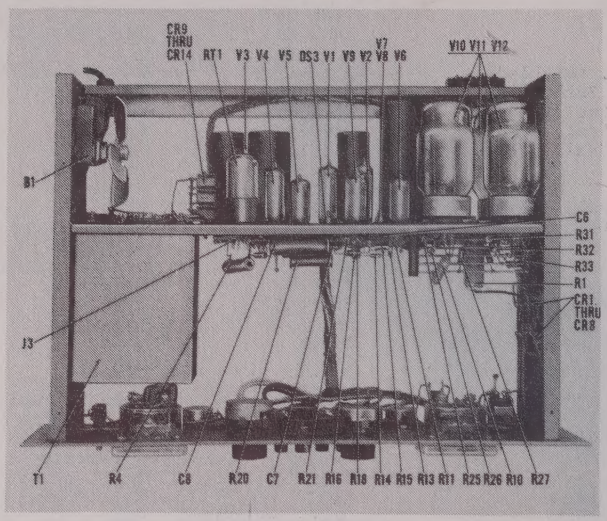

Figure 4-2. Parts Location, Top View

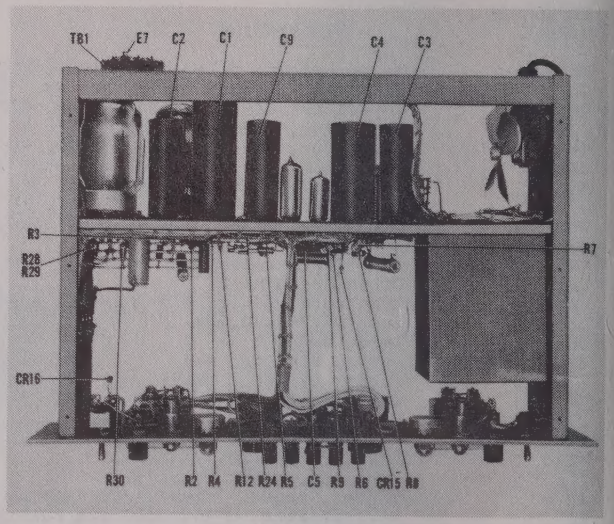

Figure 4-3. Parts Location, Bottom View

ELECTRICAL PARTS LIST

CHOPPER STABILIZATION UNIT

336B34

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
C1	Capacitor, mica, 27 UUF ±5%, 500 VDC	CM19B270J	Arco
C2,3,4	Capacitor, mylar, 0.022 UF ±10%, 200 VDC	107-0.022/200	Pyramid
C5	Capacitor, tantalum, etched foil, non-polarized, 20 UF ±20%, 25 VDC	TAE20-25SDLK-NP	*IEI
K1	Chopper, SPDT, 6.3V, 60 CPS	Model 175	Airpax
P3	Plug, octal, 8 pin	86-CP8	Amphenol
R1	Resistor, fixed, comp, 120K ±10%, ½W	EB-1241	Allen-Bradley
R2	Resistor, fixed, comp, 33K ±10%, ½W	EB-3331	Allen-Bradley
R3,6	Resistor, fixed, comp, 4.7 megohms ±10%, ½W	EB-4751	Allen-Bradley
R4	Resistor, fixed, comp, 100K ±10%, ½W	EB-1041	Allen-Bradley
R5,7	Resistor, fixed, comp, 680K ±10%, ½W	EB-6841	Allen-Bradley
R8	Resistor, fixed, comp, 56K ±10%, ½W	EB-5631	Allen-Bradley
R9	Resistor, fixed, comp, 270K ±10%, ½W	EB-2741	Allen-Bradley
R10	Resistor, fixed, comp, 1 megohm ±10%, ½W	EB-1051	Allen-Bradley
V1	Electron tube	12AX7	RCA

* International Electronic Industries, Inc.

Printed in U. S. A.

NPL

Tantalem

.68 uFd Cap.

Running 60V Rated at 50V

24 Caps In Parallel